# Non-fishery collapse of northern anchovy in California: climatic and biotic hypotheses

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# Strange Things Going On…


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## Brown Pelicans Failing to Breed

Scientists blame sardine overfishing, but climate change and El NIÑo may also be contributors.

Story Comments (4)

Posted: Friday, June 27, 2014 11:30 am

By Jimy Tallal / Special to The Malibu Times | 4 comments

Malibu seems to have more V-shaped pelican squadrons flying along the coast than ever before, and there's a reason.

Most haven't bothered to make the annual trip to the Channel Islands or Baja Mexico to breed and raise their young. In fact, experts say many haven't bothered going for the last four or five years.

The 2014 pelican breeding season is proving to be the worst yet, reaching the lowest levels recorded since the pesticide DDT, which prevented eggs from hatching, was banned in 1972. The birds had been placed on the endangered species list for over 30 years, until 2009. Now, their future is uncertain once again.

Brown Pelican


Massive Anchovy School Migrates off La Jolla

Largest Northern Anchovy school seen off Scripps in more than 30 years

Jul 08, 2014

A giant anchovy school forms a dark band off Scripps on July 8, 2014. Credit: Douglas Alden

- **Predators showing reproductive failures and mass mortalities (pelican and sea lions)**
- **But, unusually large nearshore schools of anchovies and some highly visible nearshore predator activity (humpbacks)**

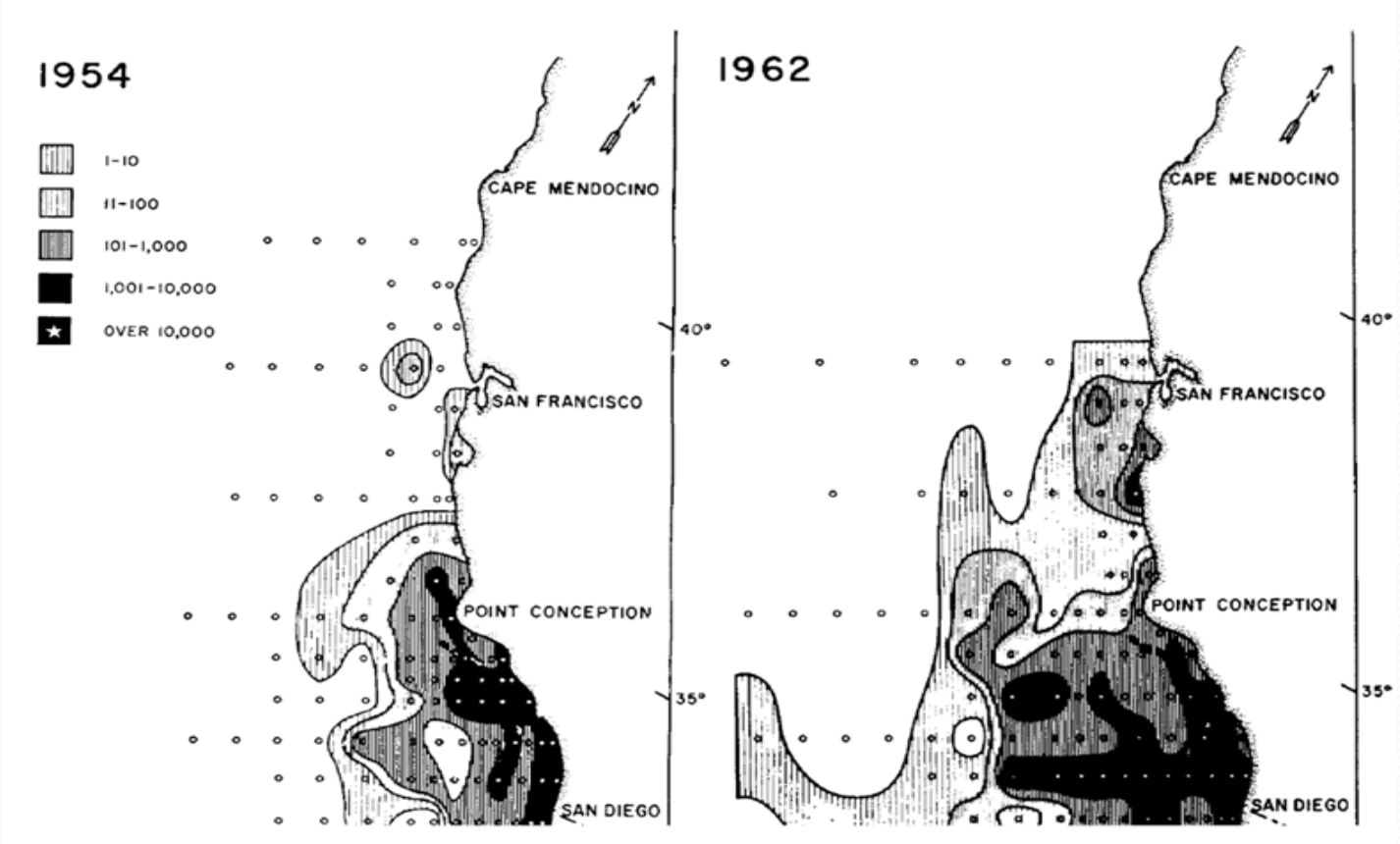
# New Effort

- Bring anchovy abundance time series up to date using CalCOFI samples (last stock assessment in 1995)
    - Examine climate factors contributing to population dynamics
    - Examine biological factors contributing to population change
- Funded by The Pew Charitable Trusts and National Fish and Wildlife Foundation
- Thanks to NMFS-SWFSC for CalCOFI data access and bringing the data backlog up-to-date

# Abundance Estimation: Possible Problem

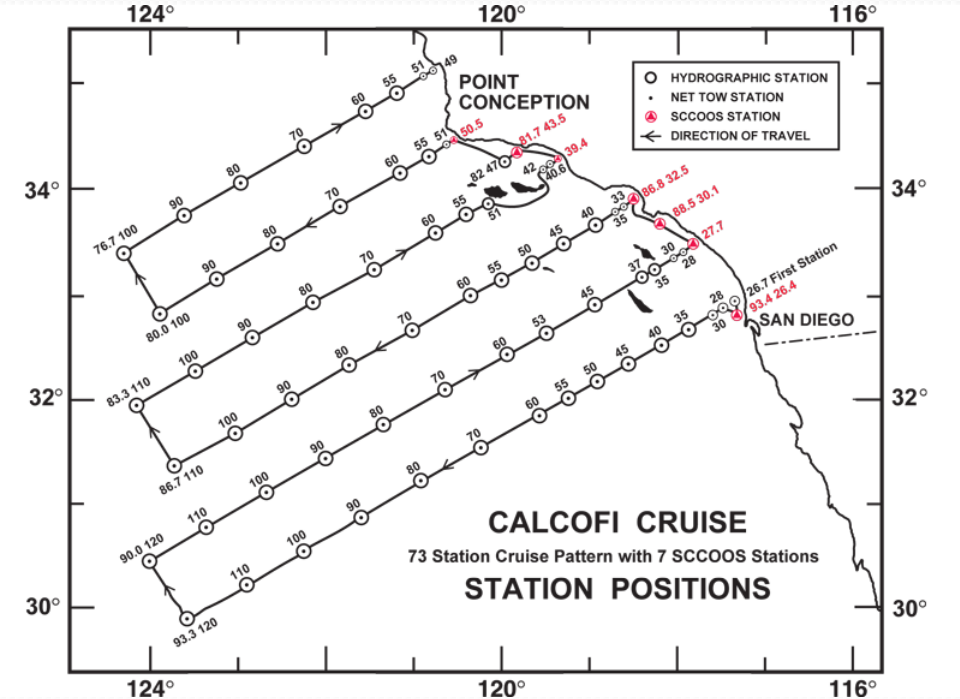
- The Historical Egg Production (HEP) approach used since the early 1980s has no spatial structure
  - All stations and times are treated as equal (*iid*)
  - This is underscored by use of bootstrap for precision
- But, anchovies tend to be nearshore at low abundance, and offshore at high abundance
  - CalCOFI stations are also more closely-spaced nearshore
- This implies that the previous HEP abundance estimates are likely to suffer from hyperstability bias
  - Estimate declines more slowly than the actual abundance

# Expansion and Contraction



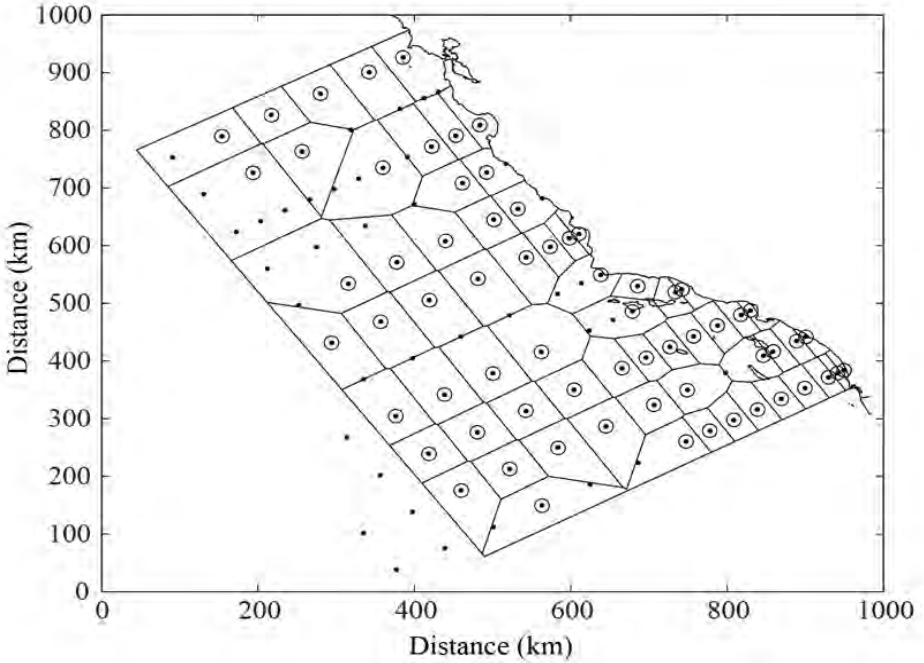
# Problem: New nearshore stations

**Stations added in 2004 are very nearshore, amplifying the potential for hyperstability bias**



# Solution: Expand to Local Area First

- Thiessen polygons
  - GIS approach
  - originally proposed by Sette and Ahlstrom (1948)
- Eliminate new nearshore stations
- Replace bootstrap by jackknife approach
  - maintains spatial structure



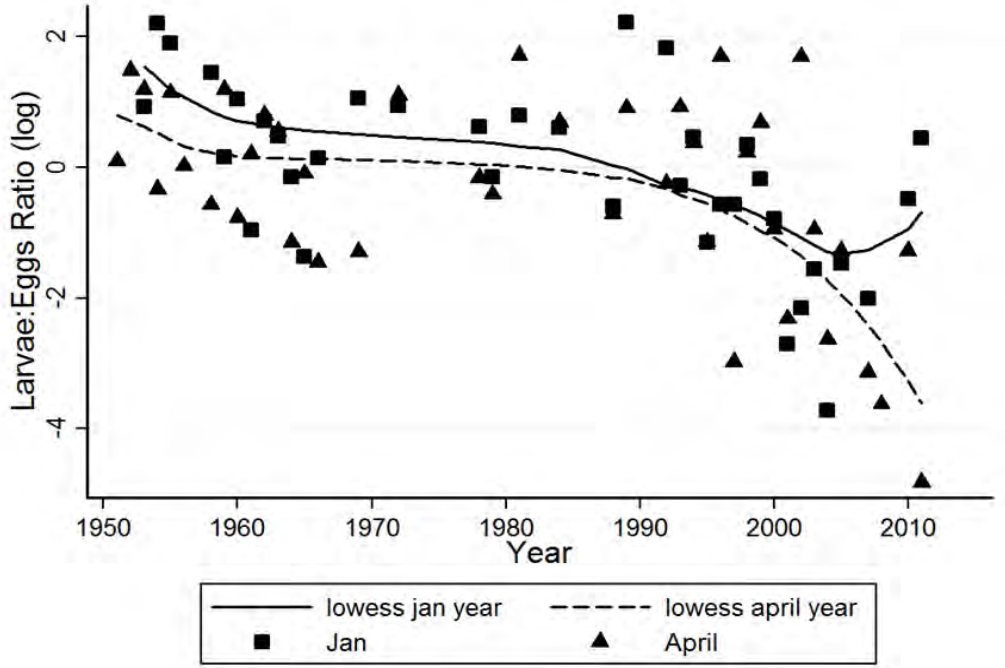

Tesselation done for each survey and each jackknife => heavy workload

# Four Time Series (Sub-Indexes)

- Use eggs and larvae as separate time series
  - Size-structured approach has merits, but was beyond our scope
  - Eggs are patchy (less precise)
  - Larvae are diffused (more precise), but are also subject to mortality issues (possibly biased)
- We use January and April as separate indexes
  - HEP treats all months as equal
  - April abundances are higher than January

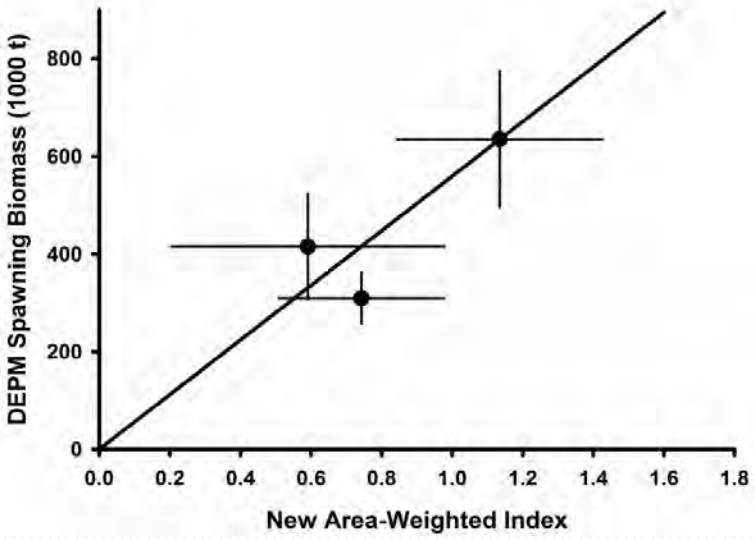
# Larvae

- Larvae have nearly disappeared since 2000
  - Fissel et al. (2011) also observed high egg mortality rates



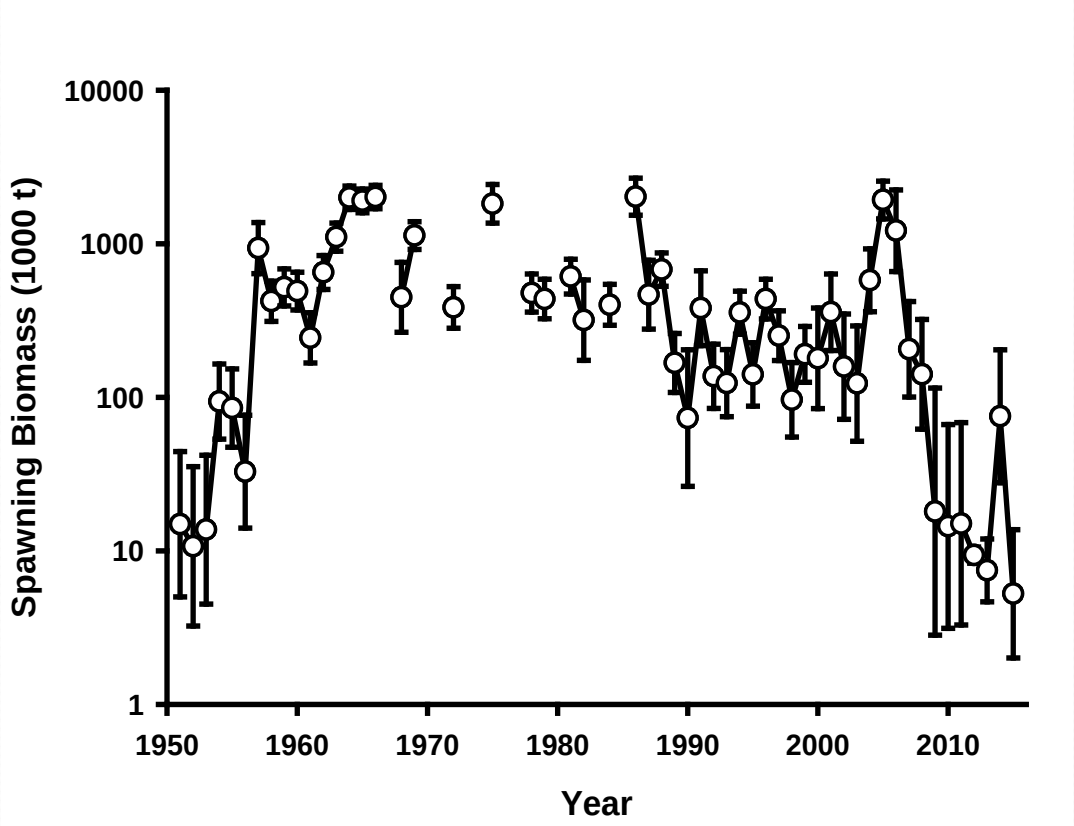
# Combined Index and Calibration

- Standardize each sub-index to unit mean
- Use their average to obtain combined index
  - PCA indicated nearly-equal weightings
- Calibrate to the DEPM biomasses from the early 1980s
  - Same as previous estimates
- Use only S. California 6 lines
  - Central California is too variable



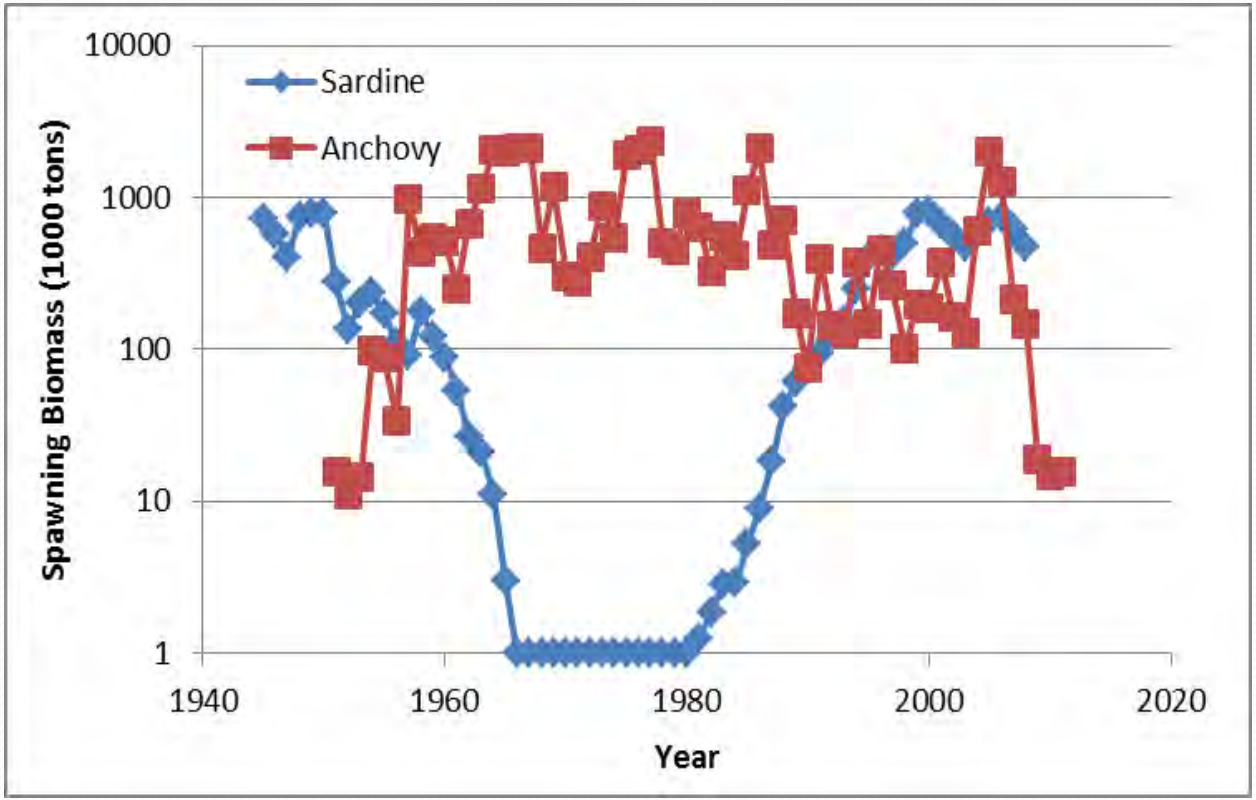
# Abundance, Log Scale View

- Est. abundance dropped by 99% in four years!
  - 2005: ~2 million t
  - 2009: ~19,000 t
- Abundance is now similar to the early 1950s
  - Estimated total abundance is less than the quota
- No recovery as of 2015



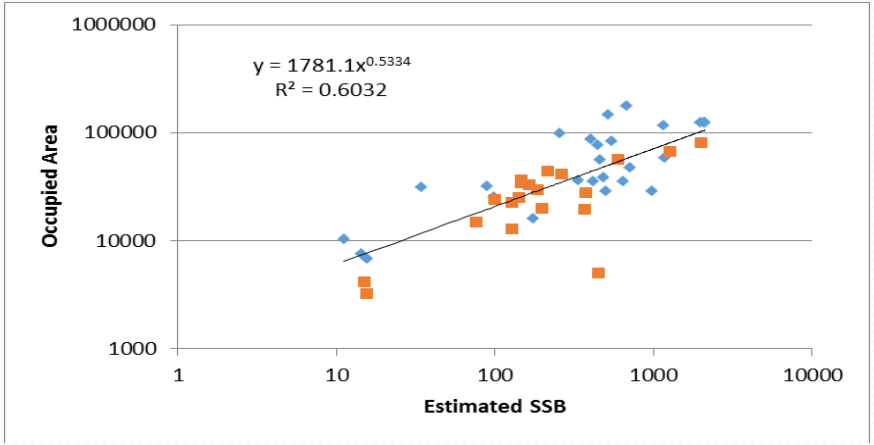
# Sardine covariate

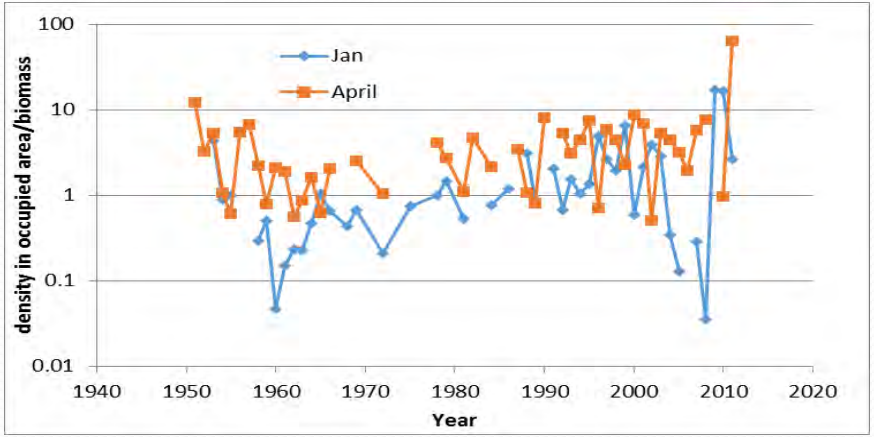
**1990: sardines exceeded 100,000 tons and 'broke out' of Southern California**



# Area Occupied Covariate

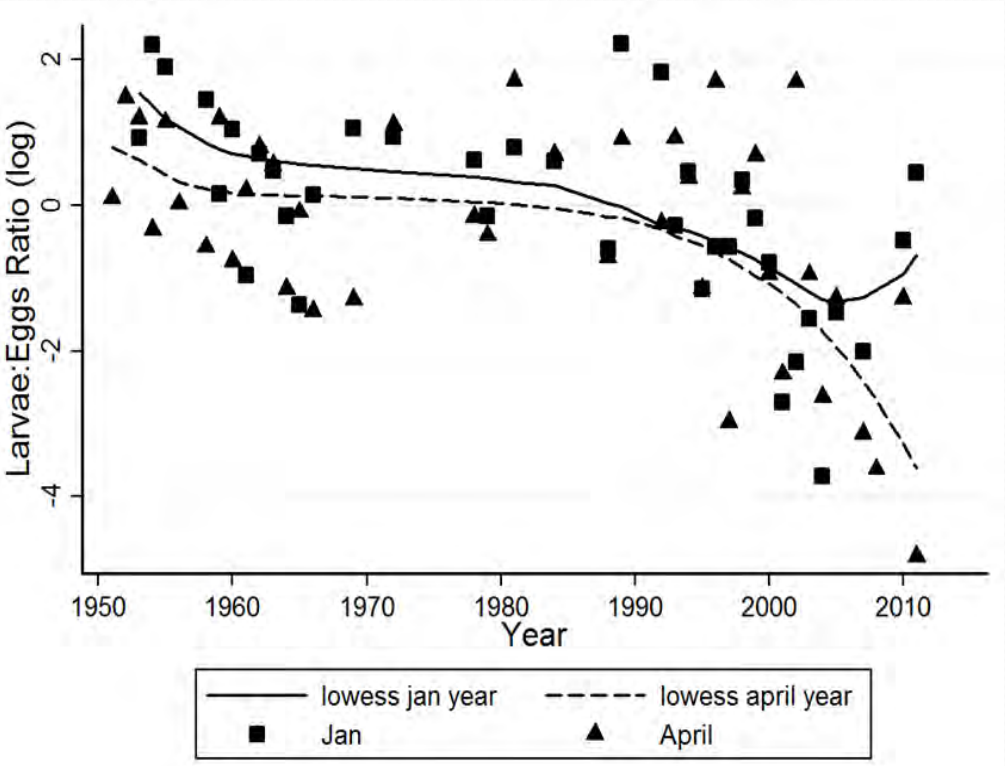
- Our polygon approach provides useful insights
- Occupied area varies as square root of biomass
- Within the declining occupied area, the anchovy density per unit biomass increased
- The anchovy population was compressed
    - Consistent with increase in coefficient of density dependence



# Also…

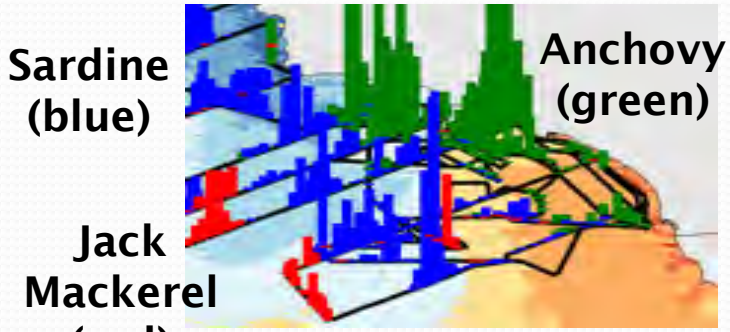
- The severe decline in egg survival is consistent with compression
- "Normal" cannibalism rates are *ca.* 10%/day
    - CA, Peru, S. Africa
- "Compressed" cannibalism rates could be 50%/day
- May explain some post-2005 failures
- Now: low B, higher M of adults due to predators and fishing

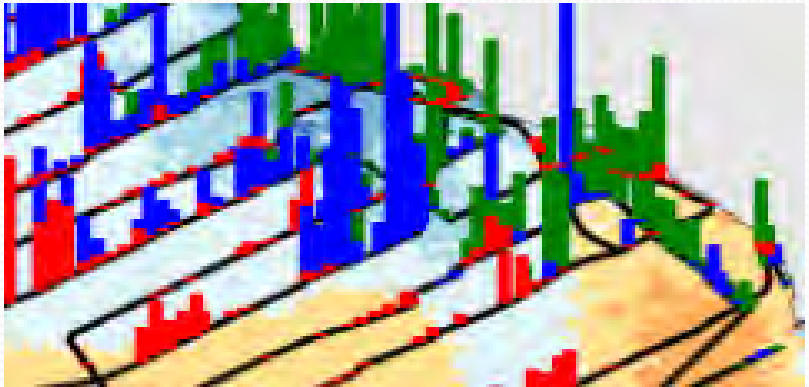


# Sardine-Anchovy Compression Hypothesis

- After 1990, sardines and anchovies partition the spawning habitat
  - Don't know how
- It is unusual to find eggs of both species in the same place
- When sardines are present, anchovies are deprived of offshore habitat/expansion
  - Anchovies can't relieve population pressure

1997 and 2005: High anchovy years



# Nearshore Distribution Revisited

*A giant anchovy school forms a dark band off Scripps on July 8, 2014. Credit: Douglas Alden.*

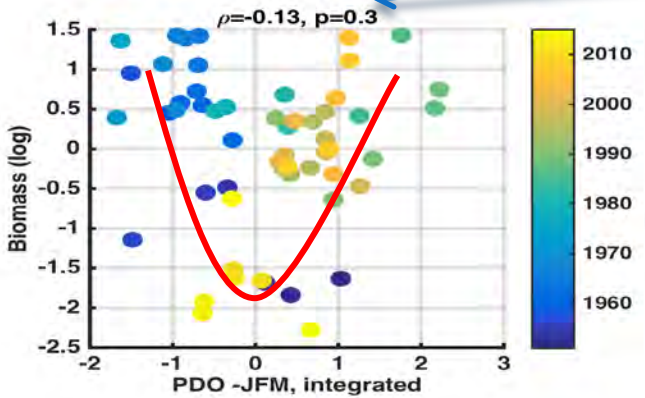
- **These fish are starving! Fish too dense, no food, cannibalism**
- **Starving fish also do not reproduce well**
- **Nearshore distribution possibly is predator avoidance, but not likely**

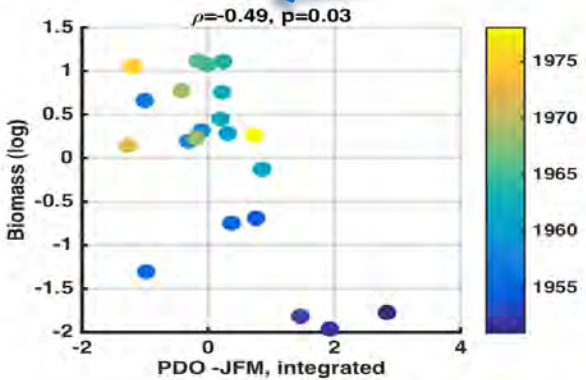
# Climate covariates (non-stationarity)

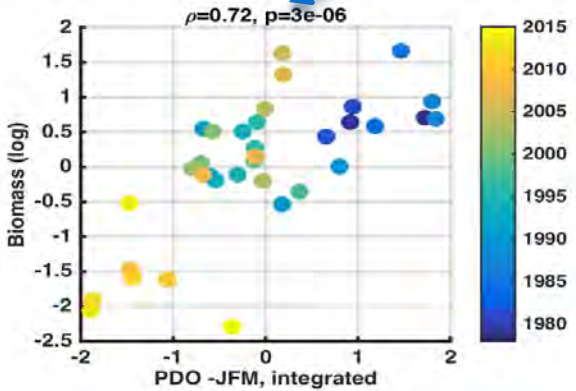
- Anchovy biomass (log)
- Environment
  - Bakun UI
  - Sea Level
  - SST
  - PDO

**January-March**
**Ranked correlation, p < 0.05**

| | Data | Integrated data | | |
|---|---|---|---|---|
| | *1951-2015* | *1951-2015* | *1951-1978* | *1978-2015* |
| BUI | -0.16 | **-0.29** | **-0.44** | -0.29 |
| Sea Level | -0.05 | **-0.4** | **-0.63** | 0.24 |
| SST | 0.13 | 0.17 | -0.28 | **0.58** |
| PDO | 0.2 | -0.13 | **-0.49** | **0.72** |



# Conclusions

- CA anchovy abundance has collapsed and remains so
  - Due to natural causes – no blame on fishing
  - 1990 tipping point seen in climatic and biotic series (sardine)
  - Industry resisting this conclusion, but J. Zwolinski et al. have confirmed our estimates using independent measures/ approach (ATS), limited series
- Present distribution is nearshore
  - High visibility gives a false sense of abundance, not to mention is anecdotal (no data!)
  - Food or predators or habitat quality? Spatial analyses needed. Krill.

# Conclusions

- No sign of recovery as of 2015/6, but recovery could be sudden and rapid
- Impacts of the current small fishery? Could be high as B is low and M (predators) appears to be already high; more M is not helpful to recovery
- Sardines have collapsed (2014), anchovy-PDO relationship now positive, etc.
- Lots to explore, “California-Benguela Joint Investigation”